

Claims

1 (Original). A process for treating a halogen-containing gas, comprising:
providing a treatment gas that includes at least one halogen-containing gas;
mixing at least one gaseous reducing agent with the treatment gas resulting in a feed gas mixture; and
generating a non-thermal plasma in the feed gas mixture in the presence of a liquid to reduce the halogen-containing gas.

2 (Original). A process according to claim 1, wherein the treatment gas comprises a mixture of about 0.000001 to about 25 volume % halogen-containing gas and at least one non-halogenated gas diluent.

3 (Original). A process according to claim 1, wherein the temperature of the feed gas mixture does not exceed about 100°C during generation of the non-thermal plasma.

4 (Original). A process according to claim 1, wherein the liquid comprises water.

5 (Previously Presented). A process according to claim 1, wherein the reducing agent is selected from hydrogen, hydrocarbon, ammonia, hydrazine, hydride, amine, water, and amide.

6 (Original). A process according to claim 1, wherein the liquid absorbs the heat produced from the reduction of the halogen-containing gas.

7 (Original). A process according to claim 1, wherein the non-thermal plasma comprises a silent discharge plasma.

8 (Original). A process according to claim 1, wherein the liquid has a boiling point of less than about 150°C and a heat of vaporization of at least about 35 kJ/mole.

9 (Original). A process for treating a halogen-containing gas, comprising:
introducing a halogen-containing gas and a reducing agent into a chamber;
introducing a liquid into the chamber;
generating a non-thermal plasma in the chamber to reduce the halogen-containing gas;
and
exhausting the resulting reduction product from the chamber.

10 (Original). A process according to claim 9, wherein the liquid flows through the chamber during generation of the non-thermal plasma.

11 (Original). A process according to claim 10, wherein the halogen-containing gas and the reducing agent flow through the chamber in a first current direction and the liquid flows through the chamber in a second current direction that is substantially co-current with the first current direction.

12 (Original). A process according to claim 10, wherein the halogen-containing gas and the reducing agent flow through the chamber in a first current direction and the liquid flows through the chamber in a second current direction that is substantially counter-current with the first current direction.

13 (Original). A process according to claim 9, wherein the chamber contains at least one electrode and the liquid flows as a film over at least a portion of the electrode.

14 (Original). A process according to claim 13, wherein the reducing agent is a gas that is introduced into the chamber by bubbling the gaseous reducing agent through the liquid film.

15 (Original). A process according to claim 9, wherein the liquid comprises water.

16 (Original). A process according to claim 13, wherein the non-thermal plasma is generated at or near a surface of the liquid film.

17 (Original). A process according to claim 9, wherein the reducing agent is selected from hydrogen, hydrocarbon, ammonia, hydrazine, hydride, amine, and amide.

18 (Original). A process according to claim 9, wherein the liquid absorbs the heat produced from the reduction of the halogen-containing gas.

19 (Original). A process according to claim 9, wherein the non-thermal plasma comprises a silent discharge plasma.

20 (Original). A process according to claim 9, wherein the temperature of the halogen-containing gas, the reducing agent, and the resulting reaction product do not exceed about 100°C during generation of the non-thermal plasma.

21 (Original). A process according to claim 9, wherein the liquid has a boiling point of less than about 150°C and a heat of vaporization of at least about 35 kJ/mole.

22 (Original). A process for treating a halogen-containing gas, comprising:
providing a treatment gas that includes at least one halogen-containing gas;
mixing at least one gaseous reducing agent with the treatment gas resulting in a feed gas mixture;

generating a non-thermal plasma in the feed gas mixture in the presence of liquid water to produce a reaction product mixture that includes a water-soluble halogen-containing reduction product; and

separating the water-soluble halogen-containing reduction product from the reaction product mixture.

23 (Original). A process according to claim 22, wherein the separating step comprises aqueous scrubbing.

24 (Original). A process for treating a halogen-containing gas, comprising:
providing a treatment gas that includes at least one halogen-containing gas;

mixing at least one gaseous reducing agent with the treatment gas resulting in a feed gas mixture;

generating a non-thermal plasma in the feed gas mixture in the presence of liquid water to reduce the halogen-containing gas and produce a water-soluble halogen-containing reduction product; and

dissolving at least a portion of the amount of the water-soluble halogen-containing reduction product into the liquid water.

25 (Original). A process for treating a halogen-containing gas, comprising:
providing a treatment gas that includes at least one halogen-containing gas;
mixing at least one gaseous reducing agent with the treatment gas resulting in a feed gas mixture; and
generating a plasma in the feed gas mixture in the presence of liquid water to reduce the halogen-containing gas.

26 (Original). A process according to claim 25, wherein the treatment gas comprises a mixture of about 0.000001 to about 25 volume % halogen-containing gas and at least one non-halogenated gas diluent.

27 (Original). A process according to claim 25, wherein the temperature of the feed gas mixture does not exceed about 100°C during generation of the plasma.

28 (Previously Presented). A process according to claim 25, wherein the reducing agent is selected from hydrogen, hydrocarbon, ammonia, hydrazine, hydride, amine, water, and amide.

29 (Original). A process according to claim 25, wherein the liquid water absorbs the heat produced from the reduction of the halogen-containing gas.

30 (Original). A process for treating fluorine gas, comprising:
providing a treatment gas that includes fluorine gas;

mixing at least one reducing agent with the treatment gas resulting in a feed gas mixture;
and
generating a non-thermal plasma in the feed gas mixture to convert the fluorine gas to hydrogen fluoride gas.

31 (Original). A process according to claim 30, wherein the treatment gas further comprises at least one non-halogenated gas.

32 (Original). A process according to claim 31, wherein the non-halogenated gas comprises nitrogen.

33 (Original). A process according to claim 30, wherein the treatment gas comprises about 0.000001 to about 25 volume % fluorine gas.

34 (Previously Presented). A process according to claim 30, wherein the reducing agent is selected from hydrogen, hydrocarbon, ammonia, hydrazine, hydride, amine, water, and amide.

35 (Original). A process according to claim 30, wherein the reducing agent comprises hydrogen.

36 (Original). A process according to claim 35, wherein the amount of hydrogen mixed with the fluorine gas is about 0.5:1 to about 4:1 $H_2:F_2$ atom molar ratio.

37 (Original). A process according to claim 30, further comprising dissolving the hydrogen fluoride in water.

38 (Original). A process for treating fluorine gas, comprising:
providing a treatment gas that includes fluorine gas;
mixing at least one gaseous reducing agent with the treatment gas resulting in a feed gas mixture; and

generating a non-thermal plasma in the feed gas mixture in the presence of a liquid to convert the fluorine gas to hydrogen fluoride gas.

39 (Original). A process according to claim 38, wherein the treatment gas further comprises at least one non-halogenated gas.

40 (Original). A process according to claim 39, wherein the non-halogenated gas comprises nitrogen.

41 (Original). A process according to claim 38, wherein the treatment gas comprises about 0.000001 to about 25 volume % fluorine gas.

42 (Previously Presented). A process according to claim 38, wherein the reducing agent is selected from hydrogen, hydrocarbon, ammonia, hydrazine, hydride, amine, water, and amide.

43 (Original). A process according to claim 38, wherein the reducing agent comprises hydrogen.

44 (Original). A process according to claim 43, wherein the amount of hydrogen mixed with the fluorine gas is about 0.5:1 to about 4:1 H₂:F₂ atom molar ratio.

45 (Original). A process according to claim 38, further comprising dissolving the hydrogen fluoride in water.

46 (Original). A process according to claim 38, wherein the liquid comprises water.

47 (Original). A process according to claim 44, wherein the liquid comprises water.

48 (Original). A process according to claim 38, wherein the liquid has a boiling point of less than about 150°C and a heat of vaporization of at least about 35 kJ/mole.

49 (Original). A process for treating fluorine gas, comprising:
providing a treatment gas that includes fluorine gas;
mixing at least one hydrogen-donating gas with the treatment gas resulting in a feed gas mixture; and
generating a non-thermal plasma in the feed gas mixture in the presence of water to convert the fluorine gas to hydrogen fluoride gas.

50 (Original). A process for treating fluorine gas, comprising:
introducing fluorine gas into a chamber;
introducing a reducing agent into the chamber;
generating a non-thermal plasma in a mixture that includes the fluorine gas and the reducing agent contained in the chamber to reduce the fluorine gas to hydrogen fluoride; and
exhausting the hydrogen fluoride from the chamber.

51 (Original). A process according to claim 50, further comprising introducing a liquid into the chamber.

52 (Original). A process according to claim 51, wherein the chamber contains at least one electrode and the liquid flows as a film over at least a portion of the electrode.

53 (Original). A process according to claim 52, wherein the reducing agent is a gas that is introduced into the chamber by bubbling the gaseous reducing agent through the liquid film.

54 (Original). A process according to claim 51, wherein the liquid comprises water.

55 (Original). A process according to claim 50, wherein the fluorine gas is included in a mixture with nitrogen.

56 (Previously Presented). A process according to claim 50, wherein the reducing agent is selected from hydrogen, hydrocarbon, ammonia, hydrazine, hydride, amine, water, and amide.

57 (Previously Presented). A process for treating a halogen-containing gas, comprising:
providing a chamber defining at least one gas inlet for receiving a feed gas mixture that includes a halogen-containing gas and a gaseous reducing agent, and at least one water inlet for receiving liquid water;
providing at least one first electrode disposed within the chamber;
providing at least one second electrode disposed within the chamber;
flowing the liquid water over at least a portion of the first electrode; and
applying electric potential to at least one of the first or second electrodes so as to generate a plasma in the feed gas mixture and reduce the halogen-containing gas.

58 (Original). A process according to claim 57, wherein a dielectric barrier is disposed on a surface of at least one of the first or second electrodes and the generated plasma comprises a non-thermal plasma.

59 (Original). A process according to claim 57, further comprising providing gas/liquid scrubbing packing material within the chamber.

60 (Original). A process for treating a halogen-containing gas, comprising:
providing a chamber defining at least one first gas inlet for receiving a halogen-containing gas, and at least one water inlet for receiving liquid water;
providing at least one first electrode disposed within the chamber and defining at least one second gas inlet for receiving a gaseous reducing agent;
providing at least one second electrode disposed within the chamber;
flowing the liquid water over at least a portion of the first electrode;
introducing the gaseous reducing agent through the liquid water and into the chamber so as to mix with the halogen-containing gas and form a feed gas mixture; and
applying electric potential to the first and second electrodes so as to generate a plasma in the feed gas mixture and reduce the halogen-containing gas.

61 (Original). A process according to claim 60, wherein a dielectric barrier is disposed on a surface of at least one of the first or second electrodes and the generated plasma comprises a non-thermal plasma.

62 (Original). A process according to claim 60, further comprising providing gas/liquid scrubbing packing material within the chamber.

Claims 63-79 (Canceled).

80 (Previously Presented). A process according to claim 4, further comprising adding at least calcium hydroxide or sodium hydroxide to the water.

81 (Previously Presented). A process according to claim 37, further comprising adding at least calcium hydroxide or sodium hydroxide to the water prior to dissolving the hydrogen fluoride in the water.

82 (Previously Presented). A process according to claim 45, further comprising adding at least calcium hydroxide or sodium hydroxide to the water prior to dissolving the hydrogen fluoride in the water.

83 (Previously Presented). A process according to claim 56, further comprising adding at least calcium hydroxide or sodium hydroxide to the water.

84 (Previously Presented). A process according to claim 1, further comprising vaporizing a liquid reducing agent to produce the gaseous reducing agent for mixing with the treatment gas.

85 (Previously Presented). A process according to claim 22, further comprising vaporizing a liquid reducing agent to produce the gaseous reducing agent for mixing with the treatment gas.

86 (Previously Presented). A process according to claim 30, further comprising vaporizing a liquid reducing agent to produce the gaseous reducing agent for mixing with the treatment gas.

87 (Previously Presented). A process according to claim 50, wherein the reducing agent is introduced into the chamber as a liquid that is subsequently vaporized within the chamber.

88 (Previously Presented). A process for treating a halogen-containing gas, comprising:
providing a treatment gas that includes at least one halogen-containing gas;
providing a liquid;
vaporizing a portion of the liquid;
mixing the vaporized liquid portion with the treatment gas resulting in a reaction mixture;
and
generating a non-thermal plasma in the reaction mixture in the presence of the non-vaporized portion of the liquid to reduce the halogen-containing gas.

89 (Previously Presented). The process according to claim 88, wherein the liquid comprises water.

90 (Previously Presented). The process according to claim 88, wherein the vaporizing of a portion of the liquid is effected by the liquid absorbing heat produced by the reduction of the halogen-containing gas.

91 (Previously Presented). A process for treating fluorine gas, comprising:
introducing fluorine gas into a chamber;
introducing liquid water into the chamber;
vaporizing a portion of the liquid water in the chamber; and
generating a plasma in the chamber in the presence of the non-vaporized portion of the liquid water to convert the fluorine gas to hydrogen fluoride gas.

92 (Previously Presented). The process according to claim 91, wherein the plasma comprises a non-thermal plasma.

Claims 93-95 (Canceled).